# BIOLOGICAL PEST MANAGEMENT FOR

# INTERIOR PLANTSCAPES

Alberta

Front centre photograph *Leptomastix dactylopii*, parasite of citrus mealybug. Jack Scott.
Surrounding photographs: Muttart Conservatory, Edmonton, Alberta. Marilyn Steiner.

# BIOLOGICAL PEST MANAGEMENT FOR INTERIOR PLANTSCAPES

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* Funded under Federal/B.C. Government Contract

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AECV83-E1
March 1983

This report may be cited as:
Steiner, M.Y. and D.P. Elliott. Biological pest management for interior plantscapes. Vegreville, AB. Alberta Environmental Centre. 30p. 1983. AECV83-E1

ISBN: 0-919975-00-3

Copies of this publication may be obtained from:

The Entomology Section
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Vegreville, AB
T0B 4L0 Phone: (403) 632-6761

The Publications Office
Ministry of Agriculture and Food
Parliament Buildings
Victoria, BC
V8W 2Z7 Phone: (604) 387-5121

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## ACKNOWLEDGEMENTS

Appreciation is extended to the staff at the Muttart Conservatory, Edmonton, Alberta, and the Crystal Gardens, Victoria, British Columbia, for their cooperation and use of their facilities for developing biological control recommendations; also to Linda Gilkeson, McGill University, Montreal, for slides and current information on *Aphidoletes aphidimyza*.

# INTRODUCTION

The term 'biological control' refers to the use of living organisms to control other, less desirable, living organisms. Biological control of plant pests is a very active and growing area of research, although it is not a new concept. There are many published reports on the use of biological control agents or organisms in commercial crops such as orchards, forests, field crops and greenhouse vegetables. This booklet is intended to fill an information gap in the rapidly growing area of the interior plantscape. This now extends from public conservatories to extensive plantings in homes, hotels, shopping malls, office buildings, restaurants, schools, hospitals and other environmentally sensitive areas where it is difficult to use toxic pest control products. The information in this booklet has largely been obtained from the authors' three years' experience in using biological control organisms in interior environments in Alberta and British Columbia. Brief notes have been made on a number of minor pests that may cause problems in the absence of routine chemical treatments. Much can be said for prevention rather than cure; sanitation and quarantine procedures should be maintained and strictly applied.

Interest in biological control has expanded with recognition of the limitations of pesticides and with consumer awareness of environmental concerns. Pesticides, once the panacea for all pest problems, have lost favor as a result of insecticide resistance, high cost, phytotoxicity and potential human health hazards. The title of this booklet, however, is not intended to imply that biological control has replaced pesticides. The emphasis in this booklet is on the combined or integrated use of biological control agents with cultural and chemical control measures. The objective of this technique is not pest elimination necessarily, but pest management, whereby pests are maintained below outbreak potential and below a visible plant damage threshold, at acceptable costs in terms of time and money. Biological control is not a system that looks after itself. It requires time, commitment and an understanding of the principles involved. Properly carried out, however, the rewards are in greatly reduced pesticide use and inventory, no chemical damage to plants, far less likelihood of resistance build-up, and fewer public concerns.

## PROCEDURES

1) Establish a reliable source of biological control agents. American supply houses will channel shipments through Canadian suppliers to avoid individual import permit requirements and to reduce costs. Because the number of commercial producers is limited (see page 28 ), and shipments must be routed by air or courier service for the shortest possible delivery time, a route should be established well in advance.

2) Prepare a plan of action.
   (a) Identify all present and potential pest problems. Seek expert advice to correctly identify pests.
   (b) Establish a monitoring schedule. Check leaves from several plants at various heights and locations using a x10 power hand magnifying lens. Monitor problem plants at least once a week and others at least once a month.
   (c) Establish a schedule for predator/parasite introductions. Remember that if they are too successful they run out of food and die and must be reintroduced.

3) Prepare a control program budget. Initial costs will be higher than spraying until the system is balanced. Allow $\$3/m^2$/year initially.

4) Acquire pesticides which can be safely integrated with biological control agents. (See Recommended Pesticides, page 3, and also Table 3, pages 26 and 27 for further information on insecticides and fungicides.)

5) Keep co-workers informed. 'Accidental' sprayings of unauthorized pesticides can cause havoc.

6) Act promptly to rectify imbalances. This week's build-up can be next week's outbreak.

7) Keep written records of successes and failures of parasite/predator introductions, and of pesticide applications and dosages.

8) Have patience. There are no instant results with biological control agents because of the lag time between introduction and multiplication. Start with low pest populations and be prepared to step in and augment with spot chemical applications.

# RECOMMENDED PESTICIDES

The following pesticides can be safely used with biological control organisms if used as directed.

**Insecticidal Soap** — This material is effective against most of the common pests. Coverage should be thorough. Although it may be toxic to a variable degree to exposed stages of biological control organisms, its lack of insecticidal properties once dry makes it a useful material where such organisms are absent or where localized treatments are necessary.

**Fenbutatin-oxide (Vendex$^{R}$)** — A miticide used to control several species of plant-feeding mites, including two-spotted and citrus red mites. It is relatively harmless to *Phytoseiulus persimilis*, so can safely be used where mite control is required. It does not affect other biological control agents.

**Kinoprene (Enstar$^{R}$)** — An insect growth regulator with very low mammalian toxicity. Expensive, but a valuable aid in the control of homopterous insects such as scales, mealybugs, whitefly and aphids. It is less effective against green peach aphid. Harmless to biological control agents.

**Pirimicarb (Pirimor$^{R}$)** — Because this material is fairly toxic its use should be restricted to spot treatment for aphid control. It has limited activity against other pests and is not always very effective against some strains of green peach aphid, particularly on flower buds. It does not appear to affect the more commonly used biological control agents, but care should be taken when using the midge *Aphidoletes aphidimyza* since this material has some activity against fly species.

**Diazinon** — Use of diazinon is restricted to soil drenches for soil-dwelling stages of thrips and soil pests such as sowbugs and millipedes. Canadian strains of *Phytoseiulus persimilis* are selected for resistance to diazinon.

**Bacillus thuringiensis** (Dipel$^{R}$, Thuricide$^{R}$) — A bacterial insecticide used mainly against caterpillars. Harmless to mammals, birds, fish and biological control agents. The active components are bacterial spores and crystals of a toxin produced by the bacterium. When eaten by the caterpillar, these crystals cause paralysis and disturb the gut. The spores germinate, allowing the bacteria to escape, multiply, and eventually invade the blood. Death of the caterpillar may take several days, but feeding ceases shortly after ingestion of the spray deposit. Good coverage is essential.

NEW DEVELOPMENTS

**Vertalec$^{R}$, Mycotal$^{R}$** are commercial formulations of the insect-pathogenic fungus *Verticillium lecanii* which infect aphids and whitefly, respectively. Their shelf life is short and they must be kept in cool storage. Commercially available in Europe, but not yet in Canada.

**Neocide$^{R}$** is a product available commercially in the United States and experimentally in Canada. It consists of a live insect-parasitic nematode, *Neoaplectana carpocapsae*, in association with a bacterium. In nature it has a wide variety of insect host species. Because it requires very high humidity, no sunlight, and temperatures between 16 and 32°C, it is best suited for soil applications and other areas sheltered from environmental extremes. Promising results have been obtained from its use against root weevils and tree borers.

For additional information on insecticides and fungicides compatible with biological control organisms, see pages 26 and 27.

# MAJOR PESTS AND THEIR CONTROL

Indoor plantscapes vary considerably in plant material, environmental conditions, and microhabitats suitable for pests and their biological control agents. The recommendations given in this booklet can thus only be guidelines and the user should feel free to experiment.

## TWO-SPOTTED SPIDER MITE, *Tetranychus urticae*

Sometimes known as the red spider mite or glasshouse spider mite, this pest is the one most frequently encountered in indoor plant environments, and most biological control programs should be centred around it. Its extensive host range, short generation time, continuous reproduction and resistance to many miticides often makes long-term control by conventional means a frustrating experience.

**Damage** — Mites feed by piercing plant cells with the mouthparts and sucking up the cell contents, thereby causing white speckles on the leaves. In severe infestations, browning and drying of foliage is evident and fine webbing laid by the mites can be seen on upper plant parts.

**Occurrence** — Two-spotted spider mites can be found on all areas of the plant, most often on middle-aged leaves unless the infestation is severe, in which case they congregate at the tips. With some exceptions, the lower surface of the leaf is favored over the upper surface.

**Appearance and life history** — Adult mites are very small, oval-shaped and yellowish or greenish except for two dark spots on the back. Males are slightly smaller and slimmer than females. Young mites hatch from pearly white, circular eggs laid among the webbing on the leaf. They resemble adults except in size, and pass through three growth stages before reaching adulthood. In the fall, with decreasing daylength and cooler temperatures, adult females normally change to a light red color and hibernate in cracks and crevices. Indoors, in a constantly warm environment under supplementary lighting, only a few will enter the red hibernating phase.

Two-spotted spider mite egg laying and development is affected by temperature. At an optimum temperature of 30°C, a female mite may lay 100 eggs and live 30 days. A new generation is produced every 8 days. At 21°C, however, this takes 14 days, and at 12°C (the minimum temperature suitable for development) the process takes over 40 days. Potential offspring from one mite under optimum conditions would be a staggering 13,000,000 during her lifetime. Fortunately not all survive.

**Cultural control** — Mist plants frequently since spider mites dislike high humidity. Avoid high temperatures. Consider carefully if plant species highly susceptible to spider mite infestation and/or injury are worth their keep. Remove them if not!

### Biological control

Predators — A predatory mite, *Phytoseiulus persimilis*, used in greenhouses in Europe and Canada for several years, is commercially available. The adult is shiny orange in color; immature stages are a pale salmon color. *Phytoseiulus* may be distinguished from the 'red' two-spotted spider mite by its lack of spots, pear-shaped body, longer front legs and rapid movement when disturbed or exposed to bright light. Optimum temperatures for development are 21-27°C. The female lays

about 50 eggs which at favorable temperatures develop to adults in less than a week, allowing them to multiply twice as fast as their prey. They can consume 5-20 eggs or mites a day. They do not hibernate under greenhouse conditions. Temperatures over 30°C and bright light are unfavorable and are avoided. Parts of plants in bright hot sunlight will thus favor spider mites and may result in poor control in these areas.

To use *Phytoseiulus persimilis:*

1. Avoid using residual pesticides in the month prior to introduction.
2. Introduce *Phytoseiulus* at first sign of spider mite damage. If there is more than an average of 1 mite/leaf, reduce spider mite populations with Vendex or insecticidal soap* until no more than 10% of the leaves have mites.
3. Adjust temperature to favor *Phytoseiulus* (21-27°C) and keep humidity high.
4. Order *Phytoseiulus* at the rate of 20/m$^2$ of planted area, 2/damaged leaf or 2/plant if plants are small.
5. Distribute *Phytoseiulus* according to susceptibility of each plant species to spider mites and to degree of infestation. Place on mid and upper foliage, preferably in early morning. Release in all infested areas. Predatory mites are mobile and will distribute themselves once they have cleaned up the area in which they have been placed. Avoid hosing down foliage. Misting is preferable and will assist in spider mite control without dislodging the predators.
6. Monitor spider mite populations at least once a week by checking new growth on all susceptible plants.
7. Reintroduce *Phytoseiulus* at regular monthly intervals. Initially, it may be necessary to reintroduce every 2 weeks until a balance has been attained, or to vary the number of predators depending on the type of planting and environmental conditions. Good control of a moderate spider mite infestation should be achieved within 4-6 weeks.

Other predatory mites are available and may be used to supplement *Phytoseiulus* (see Table 4). *Metaseiulus occidentalis* and *Amblyseius californicus* are smaller, pale colored predator mites. The former operates well at cooler temperatures and the latter at warmer temperatures.

**Chemical control** — Quarantine new plants and treat routinely with Vendex or insecticidal soap before placing among established plants. On established plants, assess whether spider mites are already being controlled adequately by *Phytoseiulus* before spraying. As a rough rule of thumb, plants with 1 *Phytoseiulus* for every 5 spider mites, or 1 leaf with *Phytoseiulus* for every 5 leaves on the same plant with spider mites should not require spraying unless populations are high enough to cause damage. This will be a function of plant species and environmental factors and can only be determined by experience on the part of the person monitoring. If general spider mite populations are high, reduce them with Vendex at label rates. Where infestations are localized, spot spray with either Vendex or insecticidal soap. Reintroduce predators or transfer from other locations.

### GREENHOUSE WHITEFLY, *Trialeurodes vaporariorum*

The greenhouse whitefly has a more limited host range than the two-spotted spider mite. It is nonetheless a common pest in conservatories, though less so in other

*See comments page 3.

interior plantscapes because of the lack of suitable host plants. A good deal of information has been developed on biological control of this pest on cucumbers and tomatoes. In ornamental plantings this pest can breed year round. Success with biological control has been variable.

**Damage** — Whiteflies are sap-sucking insects in both the adult and juvenile stages. Heavily infested plants may wilt, turn yellow and grow poorly. Whiteflies also excrete a sticky material called honeydew which covers leaf surfaces and allows the growth of an unsightly black sooty mold.

**Occurrence** — This pest is fairly structured in its distribution on the host plant. Adults generally frequent the under surface of the top leaves of actively growing shoots. Nymphs or immature stages are to be found on younger expanded leaves. Older leaves generally bear the empty pupal 'skins' left behind by emerging adults. Whitefly populations can be expected to increase whenever growth conditions for their plant host are ideal.

**Appearance and life history** — Adult whiteflies, as their name suggests, are tiny white fly-like insects which fly when disturbed. The female lays 200-400 eggs on the underside of the leaves, setting them individually on small stalks, or on some plants, in a circle by pivoting her abdomen around as she lays. The young nymphs resemble tiny mealybugs or aphids when first hatched, but they do not move very far before settling down to a sedentary existence. After the first molt, they lose their legs and resemble small white oval scales. They molt through a total of four 'instar' or growth stages to a pupa-like stage, from which the adult emerges through a T-shaped slit cut in the outer skin.

The minimum temperature for development is 8°C. Reported development time from egg to adult varies, but is on average 57 days at 15°C, 35 days at 18°C, 26 days at 21°C, 22 days at 24°C, 21 days at 27°C and 18 days at 30°C. The shorter life cycle at higher temperatures is offset by a decrease in the number of eggs laid (from more than 300 at 18°C to less than 30 at 27°C), and also a shorter adult lifespan (42 days at 18°C to 8 days at 27°C) so that the optimum temperature range for population increase is 18-24°C.

**Cultural control** — Select cultivars or plant species least susceptible to whitefly infestations. Misting is necessary to remove accumulations of honeydew and sooty mold on leaves. Use yellow sticky traps where practical to trap out adult whiteflies (not if *Leptomastix* present). These can be obtained commercially or made up from pieces of stiff card or board painted a bright yellow and coated with vaseline, vaseline/mineral oil mix, or other sticky material.

**Biological control**

Predators — The green lacewing, *Chrysopa carnea*, will provide some control if confined with infested plants. Use 4-5 eggs/plant and reintroduce as necessary. It is not recommended where other biological control organisms are being used because of its omnivorous and cannibalistic habits. The adult also has a tendency to leave its environment when pest numbers are low, requiring frequent reintroductions.

Parasites — The chalcidoid wasp *Encarsia formosa* is a readily available parasite which has been in use for over 50 years. The adult wasp is about the size of a spider mite, with dark head and thorax and yellow abdomen. It makes short hopping flights, attracted by honeydew or a scent given off by the whitefly. Males are very rare. Adult females lay eggs in the third and early fourth larval growth stages of

the whitefly, and they also kill first, second and late fourth stages by feeding on them. The parasite grub feeds within the scale, which turns black within two weeks and provides a convenient way of assessing the success of the *Encarsia* introduction. Development time, adult life span and number of eggs laid is dependent on temperature. The threshold for development is 13°C. Time from egg to adult is on the average 31 days at 18°C, 24 days at 21°C, 15 days at 24°C, 12 days at 27°C and 10 days at 30°C. This is a good deal faster than the whitefly at higher temperatures. Females live 15-30 days and can lay up to 400 eggs. The grubs go through three larval and one pupal stage before the adult stage. The emerging adult cuts a small exit hole in the top of the black scale, visible if held up against the light. At its optimum development temperature of 27°C, the egg laying capacity of *Encarsia* is twice that of the whitefly. However, it is more sensitive to cold than whitefly and below 21°C, the whitefly lays ten times as many eggs as *Encarsia*. The critical temperature for good control is approximately 23°C, however, a minimum night temperature of 15°C is satisfactory as long as there are enough sunny periods to raise the mean temperature over 24 hours to 23°C. A mean temperature of 18°C will hold the *status quo*. *Encarsia* also does less well than whitefly at relative humidities exceeding 70%, and is impeded by hairy-leaved plants and by honeydew. *Encarsia* has been reported as being fully reproductive only at light intensities of 7300 lux, and intensities below 4200 lux cause high mortality. This, together with the fact that they do not become active until four hours after sunrise, probably explains the poor control sometimes obtained during the winter months in plantings not receiving adequate supplementary light.

To use *Encarsia formosa:*

1. Avoid using residual pesticides in the month prior to introduction.
2. Reduce existing whitefly populations with either insecticidal soap* or Enstar until there is on the average less than 1 adult/upper leaf. This is a crude estimate only since populations are very dependent on environment and host.
3. Adjust temperature, humidity and light to favor *Encarsia* (23-27°C, 50-70% RH, >7000 lux, respectively).
4. Once populations are low or at first sign of adult whiteflies, order *Encarsia* at the rate of 10/$m^2$ of planted area or 1-5/plant, depending on susceptibility and size of host plants.
5. Distribute leaves or other substrates bearing black, parasitized scales in shady places on infested plants.
6. Reintroduce *Encarsia* every 10-14 days for a total of *four* introductions. This is important since adult *Encarsia* presence should correspond with the third and fourth instar whitefly stages to be attacked. Repeat this series if necessary, usually one or twice a year.
7. Monitor plants at least once a week by checking new growth on all susceptible plants. Black scales should be present within 2-3 weeks and good control achieved within 2-3 months. After one month about 20% of the whitefly scales should have turned black. If this figure is much lower, further introductions should be made. If leaves with black scales are removed, leave them among plantings for two weeks to allow emergence of *Encarsia*. Because of the longer life cycle of whitefly and *Encarsia*, control is a slower process than for spider

*See comments page 3.

M. Herbut

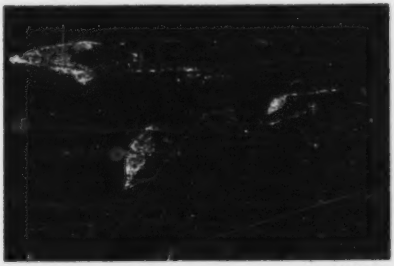
Two-spotted spider mite, *Tetranychus urticae*

H. Philip

Two-spotted spider mite webbing on rose

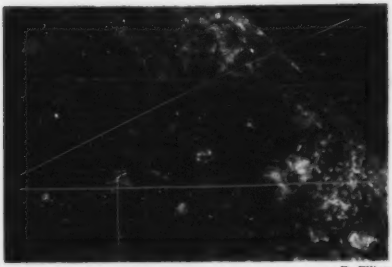
M. Herbut

Citrus red mite, *Panonychus citri*



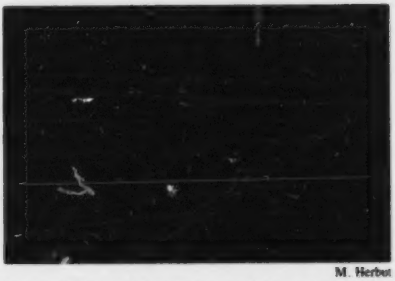
M. Herbut

Citrus red mite damage to weeping fig



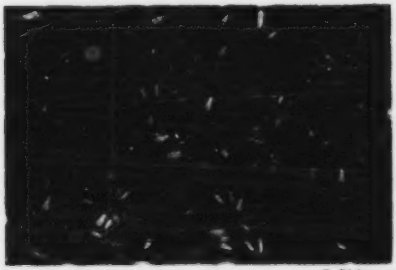
D. Elliott

*Phytoseiulus persimilis*, a predatory mite



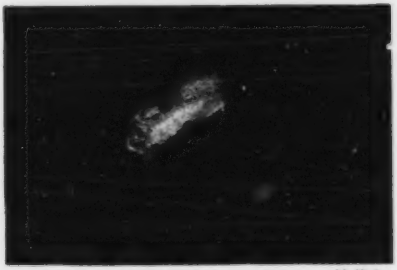
M. Herbut

*Metaseiulus occidentalis*, a predatory mite



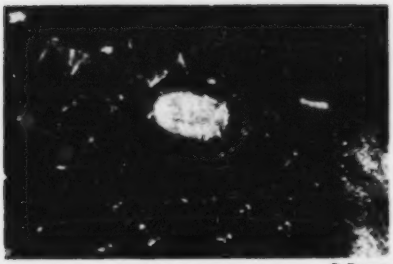
P. Dickenson

Greenhouse whitefly, *Trialeurodes vaporariorum*



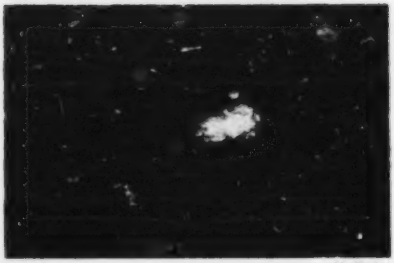
M. Herbut

Greenhouse whitefly, *Trialeurodes vaporariorum* (adult)



P. Everson

Unparasitized (white) and parasitized (black) whitefly nymphs

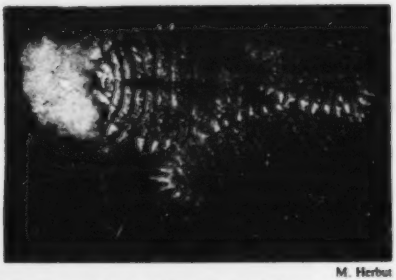


M. Herbut

Whitefly parasite, *Encarsia formosa* (adult)

P. Dickenson

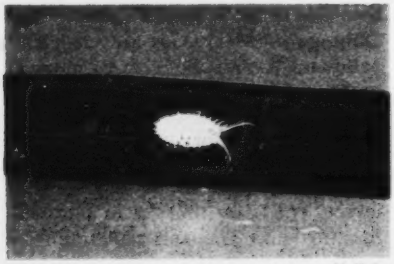
Whitefly nymphs, heavily parasitized by *Encarsia formosa*



M. Herbut

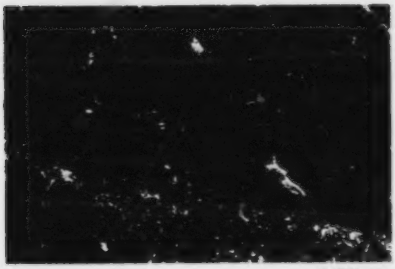
Citrus mealybug, *Planococcus citri*

Long-tailed mealybug, *Pseudococcus longispinus*



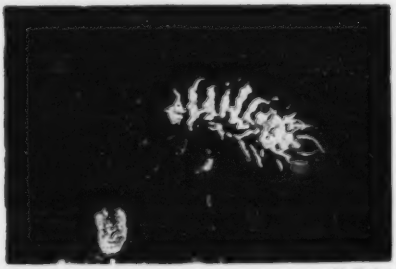
M. Herbut

Obscure mealybug, *Pseudococcus obscurus*



P. Dickenson

Mealybug predator, *Cryptolaemus montrouzieri* (adult)



M. Herbut

Mealybug predator, *Cryptolaemus montrouzieri* (larva)

mites. Integrate with chemical controls where necessary.

The fungus *Verticillium lecanii*, marketed for whitefly control in Europe under the trade name Mycotal, may become available in Canada in the near future. This living organism needs a minimum RH of 85% and night temperatures between 15 and 25°C for at least one week after application. It can be integrated with *Encarsia* or insecticidal soap.

**Chemical control** — Quarantine, check, and treat new plants routinely with Enstar or insecticidal soap before placing among established plants. On established plants, if adult whiteflies exceed 10/leaf, spot spray the new growth of infested plants with insecticidal soap. Among large scales, the percentage of black parasitized scales should exceed 30% after 5-6 weeks and eventually reach 75-95%. Lower parasitization rates and noticeable honeydew or detrimental effects on growth may require spot spraying of scale-bearing leaves with insecticidal soap or, preferably, with Enstar, since this does not kill *Encarsia*. If whitefly populations of more than 40 adults/leaf are not treated, honeydew and sooty mold will develop.

## CITRUS MEALYBUG, *Planococcus citri*

The citrus mealybug is the most common species found in ornamental plantings. It has an extensive host range, and thrives on soft-stemmed and succulent plants such as *Codiaeum*, oleander, *Coleus*, *Fuchsia* and cactus. Other mealybug species which may be encountered are the long-tailed, obscure, citrophilus, grape and ground mealybugs, which present special problems for biological control as no parasite is available. Fortunately they are far less common than the citrus mealybug.

**Damage** — Mealybugs are sap-sucking insects, typically distorting, stunting and yellowing foliage, but also excreting copious quantities of honeydew which attracts sooty mold and ants.

**Occurrence** — Citrus mealybugs are found on all parts of the plant, including the roots, but typically are clustered on stem tips and new growth.

**Appearance and life history** — The citrus mealybug is a soft-bodied, oval, pink insect. The body after the first growth stage is covered by a white, waxy material, forming short filaments radiating from the margins of the body. The obscure and long-tailed mealybugs are readily distinguished by their longer tail filaments. Most mealybugs mate, the seldom-observed male being a tiny, delicate, two-winged insect which does not feed. Females lay up to 600 yellow eggs over 8-10 days, placing them in a light cottony mass. They hatch in about 10 days and the crawlers migrate actively in search of feeding sites. Female nymphs go through three growth stages. Generation time may take a month to a year, depending upon temperature, 1-2 months being normal under greenhouse conditions. Although this mealybug prefers relatively high humidities, its observed success on cacti growing under semi-arid conditions attests to its adaptability.

**Cultural control** — Dislodge mealybugs by hosing down plants frequently unless biological control agents are present, in which case mist to remove honeydew accumulations. Choose plant species least susceptible to damage and infestations. Mealybugs other than citrus mealybug are one of the most difficult pests to control in indoor plantings. Check new plants carefully and discard infested plants rather than risk infesting established plants.

**Biological control**

Predators — The Australian lady beetle *Cryptolaemus montrouzieri* is available for control of all species of above-ground mealybugs, and it will also feed on aphids and immature scale insects when mealybugs are in short supply. The adult beetle is 4 mm long, black, with orange head and 'tail'. The female lays her eggs singly among the cottony egg masses of mealybugs (long-tailed mealybugs give birth to living young so beetle egg laying may be restricted). Eggs hatch in 8-9 days at 21°C, 5-6 days at 27°C. The young larva sucks out the body contents of eggs and young nymphs, passing through four instars before pupating on nearby stems, leaf undersides or structural supports. These larval stages are covered with a white, waxy material and when small, closely resemble their mealybug prey (the proverbial wolf in sheep's clothing). Check carefully before pruning off or spraying apparently mealybug-infested shoots. The larval stages of *Cryptolaemus* extend 17-24 days at 21°C, 12-17 days at 27°C, and the white pupal stages 14-20 days at 21°C and 8-10 days at 27°C, for a total development time from egg to egg of approximately 54 days at 21°C and 33 days at 27°C. Their activity threshold is 9°C; optimum temperature for egg laying and larval development is 22-25°C at 70-80% RH. During the winter months, lower temperatures and shorter daylengths appear to inhibit their activity more than it does the mealybugs', and control may be inadequate. *Cryptolaemus* needs fairly high mealybug populations to satisfy its requirements, and is best used as a quick knockdown agent for heavy mealybug infestations. In this case it is not necessary to reduce mealybug numbers before introduction unless only small numbers of beetles are to be released.

To use *Cryptolaemus montrouzieri:*

1. Control any ants in the area since these will protect mealybugs for their honeydew.
2. Avoid using residual pesticides in the month prior to introduction.
3. Adjust the temperature to favor *Cryptolaemus* (22-25°C) and screen vents and windows to prevent escape of beetles.
4. Order *Cryptolaemus* at the rate of 5/$m^2$ of planted area or 2-5/infested plant.
5. Distribute *Cryptolaemus* by releasing live adults at various infestation sites, preferably early morning or late evening so that they settle more readily on the plants. Avoid wearing white clothing while distributing — beetles are attracted to light colors.
6. Monitor plants at least once a week by checking new growth on all susceptible plants.

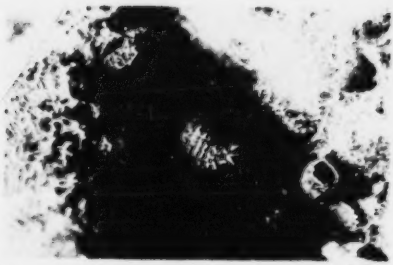
Repeat releases as necessary, usually once or twice a year under favorable conditions.

The green lacewing, *Chrysopa carnea*, also feeds on mealybugs (see page 6 for comments on its use).

Parasites — The tiny wasp *Leptomastix dactylopii*, available commercially, is a valuable supplement to the control of the citrus mealybug. It does not reproduce in other mealybug species. The female of this yellowish-brown wasp with its short, hopping flight and long, tapping antennae lays her eggs in the third stage nymph and adult mealybug. The developing wasp grub turns its host into a neat, legless,

J. Scott

Citrus mealybug parasite, *Leptomastix dactylopii* (adult)

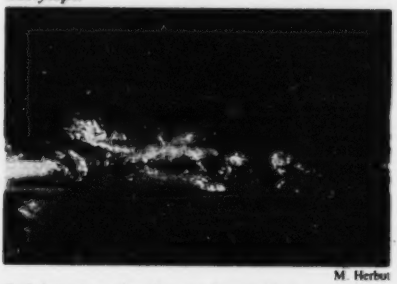


J. Scott

Citrus mealybug (centre) parsitized by *Leptomastix dactylopii*

M. Herbut

Mummified citrus mealybug after emergence of *Leptomastix dactylopii*

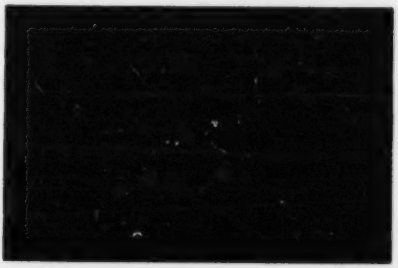


M. Herbut

Soft brown scale, *Coccus hesperidum*

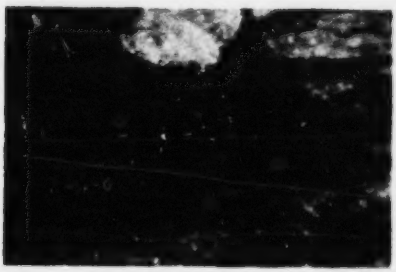
M. Herbut

Nigra scale, *Saissetia nigra*



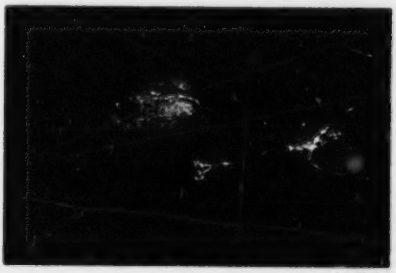
M. Herbut

Hemispherical scale, *Saissetia coffeae*



M. Herbut

Black scale, *Saissetia oleae*

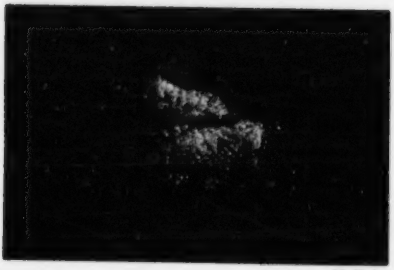


M. Herbut

Elongate soft scale, *Coccus longulus*

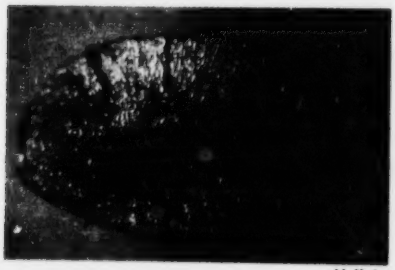
M. Herbut

Soft scale parasite, *Metaphycus helvolus* (adult)



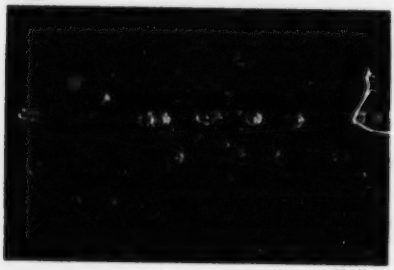
M. Herbut

*Metaphycus helvolus* (larva) within parasitized soft scale



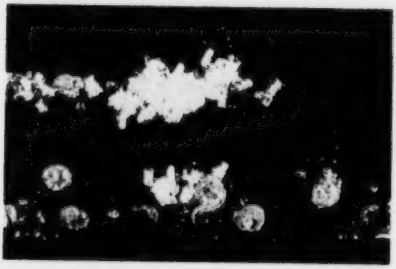
M. Herbut

*Metaphycus helvolus* (pre-adult) within parasitized soft scale



M. Herbut

Ivy (oleander) scale, *Aspidiotus nerii*



M. Herbut

Boisduval's scale, *Diaspis boisduvalii*

M. Herbut

Fer.. .cale, *Pinnaspis aspidistrae*

M. Herbut

Florida red scale, *Chrysomphalus bifasciculatus*

M. Herbut

Armoured scale parasite, *Aphytis melinus* (adult)

barrel-shaped mummy, covered with fine threads. When the adult wasp is ready to emerge, one end of the mummy unhinges to allow its exit. The adult wasp feeds on host honeydew. *Leptomastix* prefers a sunny, warm and humid environment, however, it has been used successfully in low humidity situations. Development time is 28 days at 24°C and 18 days at 27°C. Females lay an average of 80 eggs.

To use *Leptomastix dactylopii:*

1. Avoid using residual pesticides in the month prior to introduction.
2. Use *Cryptolaemus* to reduce heavy mealybug populations, or hose off dense accumulations of mealybugs with water and spray with either Enstar or, if no other biological control agents are present, with insecticidal soap.
3. Adjust temperature to favor *Leptomastix* (24-27°C).
4. Order *Leptomastix* at the rate of 5/$m^2$ of planted area or 5/infested plant.
5. Distribute *Leptomastix* by releasing live adults at various infestation sites.
6. Monitor plants at least once a week by checking new growth on all susceptible plants.

Repeat releases as necessary, usually once or twice a year. Good control should be achieved in 2-3 months.

**Chemical control** — Quarantine, check, and treat new plants with Enstar or insecticidal soap before placing among established plants.

Guidelines for control are difficult to quantify for mealybugs because of their tendency to aggregate on growing tips on some plants and distribute themselves on others. In general, spot spray where female mealybugs with egg sacs are present but no *Cryptolaemus* or *Leptomastix*-parasitized individuals, particularly if growing tips are infested or the plant is sensitive to damage. The percentage of mealybugs parasitized by *Leptomastix* should exceed 50%. Use Enstar if parasites or predators are present, insecticidal soap if not. Repeat as necessary in 7-10 days or introduce more parasites and/or predators.

**SOFT SCALES (Coccids)**

Several species of soft scale are included under this heading. Extensive use has been made of biological control agents for scale insect control in many areas of the world on outdoor crops, but little work has been done on indoor plantings and information on life histories of both scales and their natural regulators under these conditions is scanty or lacking. Some success has been achieved with a commercially available parasite, and the search for others is continuing.

**Damage** — Soft scales are related to mealybugs and inflict similar damage. They are sap suckers, typically distorting, stunting and yellowing foliage. Similarly, they excrete large quantities of honeydew, which is a useful indication of the presence of these often unnoticed pests.

**Occurrence** — Soft scales generally frequent the undersides of leaves and stems, but may be found on upper leaf surfaces also, depending upon the host plant and scale species. Both young and older leaves may be attacked, but scales on the stems usually select new growth.

**Appearance and life history** — In their outdoor habitats, scale insects generally

only produce 1 or 2 generations a year. In the greenhouse there may be 3-6 generations, often overlapping if conditions remain constant. In general, the female scale lays as many as 2,000 eggs beneath her hard outer shell. After several days or weeks these hatch into mealybug-like crawlers which migrate over the plant looking for suitable feeding sites. The mortality rate of these scales is very high. The survivors, once they have settled down, go through three growth stages. The rare adult males are tiny, delicate, winged or wingless insects. Immature scales are paler and flatter than the adult female. Eggs are laid over several weeks and the female then dies. Most scales dislike extremes of temperature, but thrive in fairly humid warm temperature conditions and shade.

The following species of soft scale are the ones most commonly encountered in indoor plant environments:

1) Black scale, *Saissetia oleae*, prefers woody plant hosts which include weeping fig, citrus, banana and olive. Black or dark brown in color, oval and convex, it is readily recognized by a raised H-shape on the upper surface and somewhat roughened appearance.
2) Hemispherical scale, *Saissetia coffeae*, is a smooth, strongly convex shiny brown scale, roughly circular in outline. Immature stages are white and have the 'H' pattern typical of the black scale. Its host plants include ferns, *Schefflera*, asparagus fern and many non-woody evergreen plants.
3) Soft brown scale, *Coccus hesperidum*, is oval and more flattened than the black and hemispherical scale. Its color is pale brown, dirty white or greyish, mottled with dark brown on the back. The shell is pliable. Females produce living young. The elongate or long, soft scale, *Coccus longulus*, is similar in appearance but more elongate. The soft brown scale is a copious honeydew excretor. Both species feed on a wide range of hosts, including *Schefflera*, weeping fig, ferns, and citrus.
4) Nigra scale, *Parasaissetia nigra*, can vary its size, shape and color depending on its host. On petioles or thin stems it may be slim and elongate; on leaf blades it is more oval. Its hard outer shell is shiny black or dark brown. Woody plants such as weeping fig, citrus, ivy and holly are its common hosts.

**Cultural control** — Prune heavily infested branches before crawlers hatch. Mist or spray with water to wash off honeydew and dislodge crawlers.

**Biological control**

Predators — The green lacewing, *Chrysopa carnea*, feeds on immature scales. See page 6 for comments on its use. *Cryptolaemus montrouzieri* will also feed on scales if mealybugs are not available. Related coccinellid beetles are far more efficient but are not yet commercially available.

Parasites — A tiny, black and yellow wasp, *Metaphycus helvolus*, is marketed which will provide variable control of several soft scale species. It is particularly effective against hemispherical scale, which produces little honeydew, but less so against soft brown scale. In our experience it provided better control of black scale under hot, semi-arid conditions than under warm, fairly humid conditions, though this may have involved factors other than climate. The female wasp lays her eggs under the body of first and second stage scales. The grub feeds on the young scale and develops to an adult within two weeks, cutting a small exit hole which can be seen with a x10 hand lens. The adult kills older non-parasitized scales directly by

M. Herbut

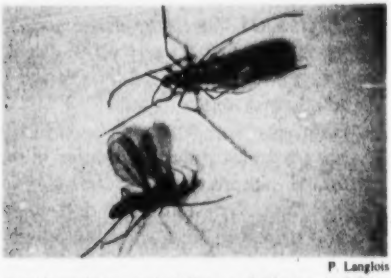
Green peach aphid, *Myzus persicae*

M. Herbut

Aphid mummified by a braconid wasp parasite

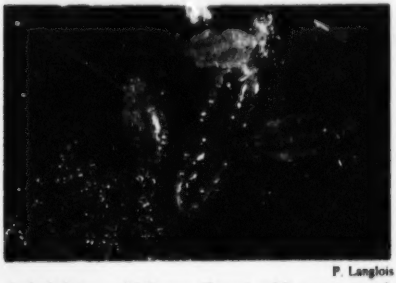
M. Herbut

A braconid wasp parasite of green peach aphid



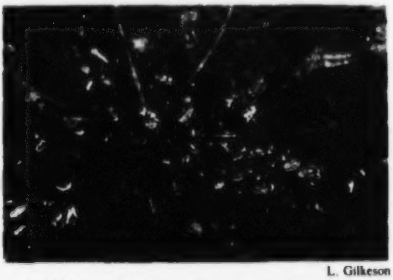
P. Langlois

Aphid predator, *Aphidoletes aphidimyza* (adult)



P. Langlois

*Aphidoletes aphidimyza* (larva) with green peach aphids

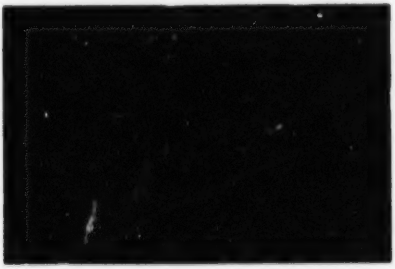


L. Gilkeson

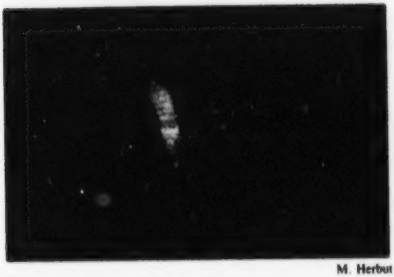
*Aphidoletes aphidimyza* (larvae) feeding on aphids

M. Herbut

Green lacewing, *Chrysopa carnea* (larva)



Green lacewing, *Chrysopa carnea* (adult)

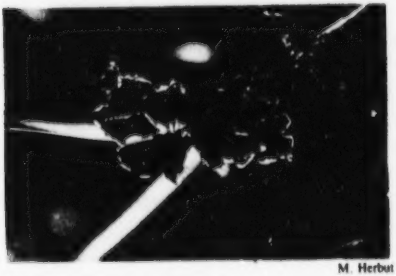


M. Herbut

Onion thrips, *Thrips tabaci*

M. Herbut

Greenhouse thrips, *Heliothrips haemorrhoidalis*

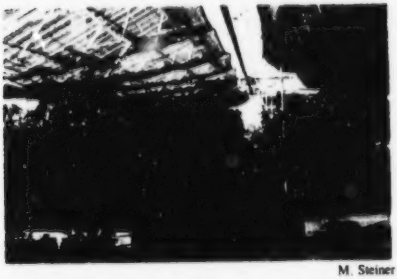


M. Herbut

Thrips damage to *Impatiens*

R. Dixon

Distributing leaves bearing *Phytoseiulus persimilis*

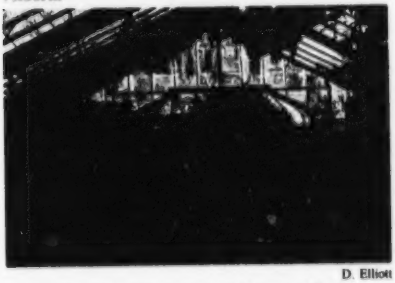


M. Steiner

Tropical plant greenhouse, City of Edmonton, Alberta

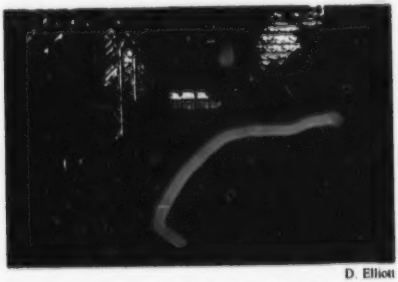
D. Elliott

Crystal Gardens, Victoria, British Columbia



D. Elliott

Calgary Zoo Conservatory, Calgary, Alberta



D. Elliott

Devonian Gardens Mall, Calgary, Alberta

feeding on them. Information on rate of development at different temperatures is lacking but it can be presumed that they like semi-tropical conditions.

To use *Metaphycus helvolus:*

1. Avoid using residual pesticides in the month prior to introduction.
2. Reduce heavy scale populations 2-3 weeks prior to introductions with insecticidal soap, or if other biological control agents are present, with Enstar.
3. Wash off accumulations of honeydew. If the leaf surface is sticky, wasps will spend their time cleaning themselves instead of searching and egg laying.
4. Adjust temperature to favor *Metaphycus* (22-29°C).
5. Order *Metaphycus helvolus* at the rate of 10/$m^2$ of planted area or 5-10/infested plant.
6. Distribute *Metaphycus* by releasing live adults on infested plants. Repeat two or three times at 2-3 week intervals and then as necessary, usually once or twice a year under favorable conditions.
7. Monitor plants at least once a week. Small scales with parasite emergence holes should be apparent within 2-3 weeks and good control achieved within 2-3 months. Removing mature adult scales manually will assist control. Wasps can sometimes be found on the underside of the leaves at the base or along the midrib.

**Chemical control** — Quarantine, check, and treat new plants with Enstar or insecticidal soap before placing among established plants. After 2-3 months, 50% or more of the small scales should be parasitized. If more than two adult scales or large numbers of crawlers are present per medium-sized leaf, spot spray with insecticidal soap, or if biological control agents are present, with Enstar. Repeat in 7-10 days if necessary. Keep honeydew washed off.

**ARMOURED SCALES (Diaspids)**

Armoured scales are less commonly encountered than soft scales but can present a problem where chemical spraying is suspended under a biological control program. They often pass unnoticed initially because of their small size and non-insect-like appearance.

**Damage** — Armoured scales are sap-sucking insects which cause further damage by injecting toxins into the plant while feeding, resulting in yellow or brown areas around the feeding sites and eventually the death of the leaf. They do not excrete honeydew.

**Occurrence** — Armoured scales are found on both leaves and stems where they may form thick crusts. They normally occur on the lower leaf surface, but sometimes also on both surfaces.

**Appearance and life history** — In general, eggs laid under the scale cover hatch into crawlers similar in appearance to mealybugs and soft scales. These wander around until they find a suitable feeding site and settle down to a sedentary existence. The skins from the first two molts are secured to the upper body by wax and become the characteristic 'nipple'. Oystershell-shaped armoured scales lay down further layers of wax while moving in an arc, hence the characteristic shape. Circular types pivot around in a circle while depositing the wax. Males are generally slimmer than females in the young stages and are winged when adult. In protected environments

there may be 3-6 generations a year.

The following species are among those which may occur on ornamentals in indoor plantings.

1) Ivy or oleander scale, *Aspidiotus nerii*, is a grey or dirty white, circular and flattened scale with a somewhat off-centred 'nipple'. It infests many indoor plants. Males are similar to females but are more oval in shape. The greedy scale, *Hemiberlesia rapax*, is similar but less flattened, and prefers to aggregate on stems.

2) The false Florida red scale, *Chrysomphalus bifasciculatus*, is another circular scale with a central 'nipple'. The color is dark red to nearly black. It feeds on leaves and fruits of plants such as palms, rubber plant, banana and figs. Similar scales are the California red scale, *Aonidiella aurantii*, which is a brighter reddish brown and prefers citrus, and the dictyospermum scale, *Chrysomphalus dictyospermi*, which is pale yellowish brown and favors palms and citrus.

3) Boisduval's scale, *Diaspis boisduvalii*. The female is circular, white and flattened, whereas the male is smaller and elongate with three powdery ridges along the back. Males congregate in cottony masses. This scale thrives on the leaves and bark of palms, banana, cacti and orchids. The cactus scale, *Diaspis echinocacti*, is similar in appearance and feeds primarily on cacti.

4) The fern scale, *Pinnaspis aspidistrae*, has an oystershell shape. Females are pale brown, males have white upper surfaces, parallel sides and three longitudinal ridges. They prefer ferns and aspidistra.

5) The purple scale, *Lepidosaphes beckii*, is dark brown or purple and oystershell-shaped. Males are slightly smaller and narrower than females and more nearly parallel-sided. It is an important citrus pest but attacks many other plant species also.

**Cultural control** — Prune heavily infested branches. Mist frequently to discourage crawlers. Isolate infested plants.

**Biological control**

Predators — The green lacewing, *Chrysopa carnea*, may provide limited control. See page 6 for comments on its use. There are many coccinellid beetle predators in nature but none is currently available commercially.

Parasites — The tiny parasitic wasp *Aphytis melinus* can be obtained for control of a limited number of armoured scale species. It reportedly controls California red and oleander scale among others. It did not establish on Boisduval's scale. *Aphytis melinus* is a tiny yellow wasp which lays her eggs on the soft body under the outer waxy shell of third stage nymphs. Successful parasitization is indicated by an exit hole in the shell two or three weeks later.
Details for introduction have not been determined, but a procedure similar to that for the soft scale parasite *Metaphycus helvolus* is suggested.

**Chemical control** — Quarantine, check, and treat new plants with Enstar or insecticidal soap before placing among established plants. On established plants, monitor for the presence of crawlers and spray with Enstar if less than 50% of scales are parasitized and the infestation is spreading, or with insecticidal soap if no predators or parasites are present. Repeat in 7-10 days as necessary.

**GREEN PEACH APHID,** *Myzus persicae*

Although green peach aphid is not the only aphid found on indoor plants, it is the one most frequently encountered and most difficult to control with conventional insecticides. Other species include the shiny light green foxglove aphid, *Alacorthum solani*, and the potato aphid, *Macrosiphum euphorbiae*, a large pink or green aphid which drops off the plant readily when disturbed.

**Damage** — Aphids cause direct damage by sucking sap, which results in wilting, deformation and retarded growth of the host plant. They also excrete sticky honeydew. Some species inject toxic saliva or viruses and mycoplasmas into plants, producing symptoms such as yellowing, spotting, stunting and curling of the foliage.

**Occurrence** — Aphids are usually clustered in large colonies on new growth, at the base of buds, and on the underside of leaves.

**Appearance and life history** — Wingless nymphs vary in color from pale green to yellow or pink, even on the same branch. Winged adults are green with a dark irregular blotch on the back and a black head and thorax. In indoor plantings, all adult aphids are winged or wingless unfertilized females which give birth to living young. Winged forms are produced when the colony becomes overcrowded. A single female may give birth to 60-100 nymphs during her 20-30 day lifetime. The young in turn may begin to reproduce themselves 6-10 days after birth so colonies can build up very rapidly. They thrive over a wide temperature range and in moderate humidity.

**Cultural control** — Prune heavily infested branches and hose off aphids with water unless predators and parasites are present.

**Biological control**

Predators — Various lady beetles and the green lacewing, *Chrysopa carnea*, will provide some control. See page 6 for comments on lacewing use. Some promising results have been obtained with a predaceous midge larva, *Aphidoletes aphidimyza*. It has been marketed in Finland and may be available in Canada in the near future. The adult midge is a small black, delicate fly which lives only a few days. After mating the female lays 100-200 tiny orange eggs on the underside of leaves close to aphid colonies and often beneath the aphids. These hatch in 3-4 days at 20°C. The larva is orange or red and up to 3 mm long. Depending on temperature and food supply, it matures in 3-5 days and then drops to the ground where it builds a cocoon 2-3 cm deep in the soil and pupates. At 20°C adults emerge in 10-14 days, a total life cycle time of 3 weeks. The threshold for larval development is approximately 6°C, and the optimum temperature is 23-25°C at 80-90% RH. Adult midges feed on aphid honeydew excretions. They are active only at night and at very low light conditions. The larva feeds on aphids by biting their knee joints, injecting a paralyzing toxin, and then, when the aphid has ceased struggling, biting into the thorax and sucking out the body contents. They may eat or kill from 4-65 aphids each, depending on aphid density.

Since this midge occurs naturally outdoors in Canada, it may be possible to find them and bring them indoors. Research is underway in Canada to breed a non-diapausing (non-hibernating) strain for eventual commercial use.

To use *Aphidoletes aphidimyza:*

1. Control ants which may protect the aphids.

2. Avoid using residual pesticides in the month prior to introduction.
3. Reduce heavy aphid populations with Enstar or insecticidal soap, but leave areas with at least 10 aphids/plant or 1 aphid/$cm^2$ to encourage egg laying by the midge.
4. Adjust temperature to favor *Aphidoletes* (20-27°C).
5. Order *Aphidoletes* at the rate of 1 pupa/3 aphids or 2-5 pupae/$m^2$ of planted area.
6. Distribute *Aphidoletes* by spreading pupae in shady areas near aphid-infested plants. Repeat releases in 7-14 days and then as necessary.
7. Monitor plants at least once a week by checking new growth on all susceptible plants.

A strain of the parasitic fungus *Verticillium lecanii*, trade name Vertalec, is being marketed in Europe and may be available in Canada soon. It requires high humidity and constant warm temperature.

Parasites — There are currently no commercially available parasites. Several native species of tiny wasps parasitize green peach aphid, however, and often these turn up without introduction through windows and vents. A sign of their presence is the black or brown mummified shells of their hosts. Aphid mummies still containing parasites (no exit hole visible) can be transferred from one area to another. Sometimes hyperparasites (parasites of the parasites) interfere with this type of control.

**Chemical control** — Quarantine, check, and treat new plants with insecticidal soap before placing among established plants. If green peach aphid builds up on blossoms or on new growth, spray the tips with insecticidal soap or Pirimor. Enstar gives poor control of this aphid but may be used more extensively for other aphid species.

If *Aphidoletes* larvae are present, avoid spraying, since they jump off the plant when disturbed and are unable to relocate aphids unless within 6 cm of them.

## CITRUS RED MITE, *Panonychus citri*

This mite is a serious citrus pest. In ornamental plantings it will also attack palms, figs, ginger, bananas and various other plants. It does not have the broad host range of the two-spotted spider mite and is far less common, though damaging when present.

**Damage** — Injury to leaves results from puncturing of plant cells to feed, which causes stippling, pale spots and a silvery appearance. Visible damage is produced by relatively low mite populations.

**Occurrence** — Citrus red mite can be found on upper and lower leaf surfaces, particularly on new growth.

**Appearance and life history** — Both adult and immature stages are dark red in color and approximate the two-spotted spider mite in size. The back is covered with long hairs set on small red protuberances visible with a hand lens. Eggs are red, almost spherical and somewhat flattened, with a stalk arising from the top. Development time is approximately 45 days at 10°C, 34 days at 12°C, 26 days at 15°C, 20 days at 18°C, 16 days at 21°C, 12 days at 24°C and 10 days at 27°C. Life span, however, decreases with temperature from 48 days at 10°C to 5 days at 27°C, so that optimum temperature for multiplication of this mite is approximately

18°C, lower than for the two-spotted spider mite. An average of 40 eggs are laid at 25°C.

**Cultural control** — Mist plants frequently and provide good growing conditions to reduce susceptibility to damage.

**Biological control**

Predators — The predatory mite *Phytoseiulus persimilis* does feed on this mite and in the process becomes a much darker red than when it feeds on two-spotted spider mite. However, in our experience it does not provide adequate control, particularly on arboreal plant species. The predatory mite *Amblyseius californicus* has provided far better control. Because of its small size it is difficult to see, so declining citrus red mite populations are the best indication that this mite is at work. In cool areas, *Metaseiulus occidentalis* may also be tried. To use these mites, follow instructions given under two-spotted spider mite.

**Chemical control** — Quarantine new plants and treat routinely with Vendex or insecticidal soap before placing among established plants. Spot spray established plants with Vendex if more than 40% of the upper leaves have citrus red mite or there are on average more than 5 mites/medium-sized leaf with no predatory mites present. If predatory mites are present, treat infested plants with Vendex if damage is occurring or the citrus red mite population is multiplying rapidly.

## THRIPS

Several species of thrips are troublesome in indoor plantings, particularly during the summer months. They often go unnoticed until damage to plants is evident and a search for the culprit is made. There is presently no satisfactory biological control for these pests.

**Damage** — Both adults and larvae feed by scraping and rasping on plant tissue and sucking up the escaping plant juices. The effect is to cause silvering, flecking and distortion of growing points, fruit and flowers. In addition, the surface may be fouled by small black drops of excretory material.

**Occurrence** — Leaves, blossoms, buds and leaf sheaths all harbor thrips.

**Appearance and life history** — Thrips are tiny, slender insects. Winged adult females lay 25-200 eggs in plant tissue. Nymphs resemble adults except that they are wingless and generally paler in color. They feed for 7-10 days before pupating, either in the ground or on the leaf depending on species. Adults emerge 4-14 days later. Males are uncommon. There are many overlapping generations a year. The greenhouse thrips, *Heliothrips haemorrhoidalis*, is a large, slow-moving, dark-brown thrips with yellow legs. It is a foliage feeder and pupates on the leaf. Larvae are glassy white with red eyes. The flower thrips *Frankliniella tritici* and *F. occidentalis* are tiny yellowish species which attack flowers. They pupate on the ground. Onion thrips, *Thrips tabaci*, is variable in color, ranging from pale yellow to dark brown. The larva is white or pale yellow. It has several hundred hosts including many vegetables and ornamentals. It feeds on both leaves and flowers. Onion thrips and flower thrips readily enter open greenhouses in the summer months.

**Cultural control** — Mist plants frequently. Soils high in organic matter seem to favor those thrips which pupate in the soil.

**Biological control** — The predatory mite *Amblyseius mackenzei* is reared in Europe

for thrips control. It was tried in Alberta in one location without noticeable effect on onion thrips.

**Chemical control** — For species which pupate in the soil, a soil surface treatment with diazinon can be integrated with the use of most predators and parasites (not *Aphidoletes)*. Repeat in 2-3 weeks. For the greenhouse thrips, which spends its entire life on the leaves, frequent spot treatments with insecticidal soap are recommended.

## TABLE 1. MINOR PEST PROBLEMS AND THEIR CONTROL

| PEST | DESCRIPTION | DAMAGE | CONTROL |
|---|---|---|---|
| Caterpillars | Fleshy larvae of moths or butterflies; soil-dwelling species are dull colored, foliage feeders generally green. | Holes chewed in foliage or flowers, or young plants cut off at ground level. | *Foliage feeders: Bacillus thuringiensis* (Dipel, Thuricide) at label rates, or handpick. *Subterranean cutworm:* Sift top 5 cm of soil around cut-off plants and remove larvae manually, or use diazinon as a soil drench or granular treatment. |
| Sowbugs | Grey, oval, flattened bodies with 7 pairs of legs. | Feed mostly on decaying plant material but also on roots and stems and sometimes leaves. | Spot treat around logs, stones and other hiding places with diazinon. |
| Slugs and Snails | Related molluscs which exude slimy mucus. Prefer damp conditions. | Rasp plant tissue leaving irregular holes; feed mainly at night. | Methiocarb (Mesurol®), 2% bait placed around or under logs and stones. |
| Ants | Variously colored black, brown, yellow or red small insects which live in colonies. | Disturb roots by burrowing. They maintain pests such as aphids, mealybugs and scale for their honeydew. | Spot-treat nest area with diazinon or use ant baits. |
| Millipedes | Flattened or rounded worm-like animals with 2 pairs of legs per body segment. May be brown or grey. | Feed mainly at night on decaying organic matter; may feed on roots, bulbs and fleshy stems. | Spot-treat around logs, stones and borders with diazinon. |
| Root Weevils | Adult weevils are dark brown or black, flightless snouted beetles. Larvae are white legless grubs with brown heads. Black vine weevil is the most common species. | Adults chew notches at night in the margin of leaves of plants such as roses, azaleas and rhododendrons. Larvae feed underground on the roots. | No safe chemical control available. Sift soil around plants with recent damage for grubs and adults, preferably in the spring before egg laying can take place. A commercially available nematode is showing some promise as a biological control agent. Diazinon may give some control of young larvae in early summer. |
| Earwigs | Brown insects, 2 cm long, with a pair of "pincers" at the rear end of the body. Usually remain hidden during the day. | Scavengers feeding on organic material. Sometimes chew holes in green plant shoots and foliage. Predaceous on some soil pests. | No safe chemical control available. Short lengths of bamboo or other hollow sticks make inconspicuous traps when laid on the ground and emptied periodically. |
| Fungus gnats | Small, delicate, sooty gray or black flies, common in wet areas. Larvae are slender, white and worm-like, with shiny black heads. | Larvae feed on decaying organic matter and when numerous may damage roots of seedlings, the base of cuttings, and young plants. Common and usually not serious. | Avoid overwatering and overuse of manure and compost. If numerous use diazinon as a soil drench in affected areas. |

## TABLE 2. SUMMARY OF PRIMARY PREDATORS AND PARASITES OF MAJOR PLANT PESTS

| PEST | PREDATOR | RATE OF INTRODUCTION | TEMPERATURE* | PARASITE | RATE OF INTRODUCTION | TEMPERATURE* |
|---|---|---|---|---|---|---|
| Two-spotted spider mite | *Phytoseiulus persimilis* | 20/$m^2$ or 2/plant | 21-27°C | | | |
| | *Metaseiulus occidentalis* | 20/$m^2$ or 2/plant | 21-27°C | | | |
| | *Amblyseius californicus* | 20/$m^2$ or 2/plant | 21-27°C | | | |
| Greenhouse whitefly | | | | *Encarsia formosa* | 10/$m^2$or 1-5/ infested plant | 23-27°C |
| Citrus mealybug | *Cryptolaemus montrouzieri* | 5/$m^2$ or 2-5/ infested plant | 22-25°C | *Leptomastix dactylopii* | 5/$m^2$ or 5/ infested plant | 24-27°C |
| Soft scale | | | | *Metaphycus helvolus* | 10/$m^2$ or 5-10/ infested plant | 22-29°C |
| Armoured scale (some) | | | | *Aphytis melinus* | 10/$m^2$ or 5-10/ infested plant | 22-29°C |
| Green peach aphid | *Aphidoletes aphidimyza* | 1 per 3 aphids or 2-5 pupae/$m^2$ | 20-27°C | Braconid and chalcid wasps | ? 5/$m^2$ or 5/ infested plant | ? 18-27°C |

*Temperature range within which the biological control agent is most effective in terms of development and control.

TABLE 3. REPORTED TOXICITY OF COMMON GREENHOUSE PESTICIDES TO VARIOUS BIOLOGICAL CONTROL AGENTS

| | *Phytoseiulus persimilis* | other predaceous mites | *Encarsia formosa* | *Cryptolaemus montrouzieri* | *Leptomastix dactylopii* | *Aphidoletes aphidimyza* | *Chrysopa carnea* | *Sympherobius barberi* | *Metaphycus helvolus* |
|---|---|---|---|---|---|---|---|---|---|
| **INSECTICIDES/MITICIDES** | | | | | | | | | |
| * Vendex (fenbutatin-oxide) S | 0 | ◐ | 0 | ? | 0 | 0 | 0 | 0 | ? |
| * Enstar (kinoprene) S | 0 | ? | 0 | ? | ? | ? | ? | 0 | ? |
| Insecticidal Soap S | ● | — | ● | ● | — | — | — | — | — |
| Pirimor (pirimicarb) S | ● | — | ● | ? | ◐ | ◐ | 0 | ? | ? |
| Diazinon S | ● | — | (7) ●● | ◐ | ● | ●● | — | ●● | — |
| Diazinon SA | ◐ | — | ◐ | — | — | ●● | — | — | — |
| Malathion S | ●● | — | ●● | — | — | ●● | — | ●● | — |
| Malathion SA | — | — | — | — | — | ●● | — | — | — |
| Pyrethrin S | ●● | — | ●● | — | ●● | ●● | ● | — | — |
| * Ambush (permethrin) S | (28) ●● | ●● | (21) ●● | — | — | ● | ● | — | — |
| Sevin (carbaryl) S | ●● | ●● | — | ●● | ●● | ●● | — | ●● | — |
| * Thiodan (endosulfan) S | (4) ●● | — | ● | — | ◐ | ● | 0 | — | — |
| Resmethrin S | (7) ●● | — | (5) ● | — | — | — | — | — | — |
| * Metasystox R (oxydemeton-methyl) S | ●● | — | ● | — | ●● | — | ●● | — | — |
| * Systox (demeton) S | | | | | | ●● | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| * Pentac (dienochlor) S | ● | — | 0 | ? | ? | 0 | — | — | ? |
| Kelthane (dicofol) S | ● | ●● | 0 | 0 | ●● | 0 | 0 | ●● | ? |
| * Plictran (cyhexatin) S | ● | ●● | 0 | ? | 0 | 0 | ●● | — | ? |
| Dipel, Thuricide (*Bacillus thuringiensis*) S | 0 | ? | 0 | ? | 0 | ? | 0 | ? | ? |
| * Lindane SA | — | — | — | — | — | — | — | — | — |
| Mesurol (methiocarb) B | — | — | — | — | — | — | — | — | — |
| * Temik (aldicarb) SA | ●● | — | — | — | — | — | — | — | — |
| * Fumigants | ●● | — | ●● | — | — | — | — | — | — |
| **FUNGICIDES** | | | | | | | | | |
| Benlate (benomyl) S | ●● | ●● | 0 | — | — | 0 | — | — | — |
| Benlate (benomyl) SA | ◒ | — | 0 | — | — | 0 | — | — | — |
| Dithane Z-28 (zineb) S | 0 | ● | 0 | ◒ | — | ● | 0 | — | — |
| Captan S | 0 | — | 0 | — | — | — | — | — | — |
| Streptomycin S | — | 0 | — | — | — | — | — | — | — |
| Daconil (chlorothalanil) S | ● | 0 | 0 | — | — | — | — | — | — |
| * Dithane M-22 (maneb) S | 0 | ●● | ● | — | 0 | — | ●● | — | — |
| Karathane (dinocap) S | 0 | — | ● | — | — | — | — | — | — |
| Sulphur S | — | ● | — | — | — | — | ◒ | — | — |
| * Rovral (iprodione) S | 0 | — | 0 | — | — | — | — | — | — |

| | | | | | |
|---|---|---|---|---|---|
| * | Commercial registration | 0 | Negligible toxicity | ? | No data but probably safe |
| S | Foliar application | ◒ | Slightly toxic | — | No data — presume toxic unless proven otherwise |
| SA | Soil application | ● | Moderately toxic to one or more stages | (5) | Residual toxicity to predator/parasite in days |
| B | Bait application | ●● | Highly toxic to one or more stages | | |

## TABLE 4. SUPPLIERS OF BIOLOGICAL CONTROL AGENTS

### Import Permits

Canadian customers wishing to order directly from U.S. suppliers are advised that due to customs restrictions, import permits must be obtained **before** live bio-controls can be shipped into Canada. The same applies to U.S. customers ordering from Canada. Permit applications may take two months or more to process and various restrictions apply.

In Canada write for application form No. 720 to: Agriculture Canada
Plant Products and Quarantine Division
Permit Office
OTTAWA K1A 0C6

In the U.S. write for application form No. 526 to: U.S. Department of Agriculture
Plant Protection and Quarantine
Federal Centre Building
HYATTSVILLE, MD 20782



**NOTE**

**Allow 3 days to 4 weeks for delivery depending upon species and availability**

| | *Phytoseiulus persimilis* | *Metaseiulus occidentalis* | *Amblyseius californicus* | *Encarsia formosa* | *Metaphycus helvolus* | *Aphytis melinus* | *Cryptolaemus montrouzieri* | *Aphidoletes aphidimyza* | *Chrysopa carnea* | *Hippodamia convergens* | *Leptomastix dactylopii* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Canada** | | | | | | | | | | | |
| Applied Bio-Nomics Ltd.<br>8801 East Saanich Road<br>SIDNEY, British Columbia<br>V8L 1H1<br>(604) 656-2123 | ● | ● | ● | ● | 0 | 0 | 0 | ● | 0 | 0 | 0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Better Yield Insects<br>13310 Riverside Drive East<br>TECUMSEH, Ontario<br>N8N 1B2<br>(519) 735-0002 | ● | | | ● | | | ● | | | | |
| Fossil Flower<br>463 Woodbine Avenue<br>TORONTO, Ontario<br>M4E 2H5<br>(416)691-6029 | | | | | | | | | 0 | | |
| **United States** — major producer/suppliers only | | | | | | | | | | | |
| Associates Insectary<br>P.O. Box 969<br>Santa Paula, CA 93060<br>(805) 933-1301 | | | | | ● | | ● | | | ● | |
| Biotactics Inc.<br>7765 - Lakeside Drive<br>Riverside, CA 92509<br>(714) 685-7681 | ● | ● | ● | | | | | | | | |
| California Green Lacewings<br>P.O. Box 2495<br>Merced, CA 95340<br>(209) 722-4985 | | | | | | | | ● | | | |
| Rincon Vitova Insectaries<br>P.O Box 95<br>Oak View, CA 93022<br>(805) 643-5407 | 0 | 0 | 0 | 0 | ● | ● | ● | ● | ● | 0 | |

● Company produces.

0 Company does not produce but can obtain through other suppliers

## FURTHER READING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3. Jordan, W.H. Jr. 1979. What's Eating Your Houseplants? (Originally published in 1977 as "Windowsill Ecology"). Rodale Press, Emmaus, PA. 229 pp.
4. Tonks, N.V. et al. 1982. Pest Problems in Small Greenhouses and Indoor Plantings. Publications Office, Ministry of Agriculture and Food, Legislative Buildings, Victoria, BC V8W 2Z7. 14 pp.
5. Gill, R.J. 1982. Five Photo Recognition Keys to the Families and Common Species of Whiteflies, Mealybugs and Soft and Armored Scale Insects of California. Department of Food and Agriculture, State of California, 1220 N. Street, Sacramento, CA 95814. 5 fold-out charts.